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ABSTRACT

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CENTER FOR THE STUDY OF READING*

Technical Report No. 21

# DEPTH OF PROCESSING AND INTERFERENCE EFFECTS IN THE LEARNING AND REMEMBERING OF SENTENCES

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Abstract

In two experiments, subjects who completed the last words of sentences they read learned more than subjects who simply read whole sentences. This facilitation was observed even with a list of sentences which were almost always completed with the wrong words. However, proactive interference attributable to acquisition errors appeared on recall and recognition tests administered after a one-week interval.

On a wide range of verbal tasks--including word lists (Hyde & Jenkins, 1969), sentences defining unfamiliar words (Anderson & Kulhavy, 1972), and prose passages (Schallert, 1976)--performance is strongly facilitated by diverse procedures that would appear to have in common only that subjects are caused to give meaningful representations to the words. This has come to be known as the depth-of-processing effect (Craik & Lockhart, 1972). One study from the genre will be detailed since it involved the same paradigm as the present research. Anderson, Goldberg, and Hidde (1971) prepared sentences such that in each the last word was semantically determined by the rest of the sentence, for instance, Elevators stop at every floor. Subjects who filled blanks in place of the last words of sentences they read aloud learned significantly more than subjects who read aloud whole sentences. The explanation for this result is that completing a sentence forces a person to meaningfully process the other words whereas a person can "read"--that is, decode into speech--a whole sentence without comprehending it. The investigators said (p. 396), "Consider the incomplete statement, Elevators stop at every _____. To complete the sentence with the word floor requires a person to bring to mind, in however fleeting a form, a meaningful representation of the rest of the sentence. Simply translating the printed words into speech will not suffice, because the mere sound of the other words cannot evoke floor. Floor is semantically rather than acoustically related to the rest of the sentence."

The idea of depth of processing now enjoys wide currency in education. One technique to make more likely "deep" processing of text material is to ask the student thought-provoking questions (Anderson & Biddle, 1975).

Research has shown that readers who receive questions that require applying a principle to new examples perform better on a subsequent test than readers asked otherwise identical questions which require applying the principle to the examples used as illustrations in the text (Watts & Anderson, 1971). Similarly, people asked paraphrased questions remember more than people given questions that repeat sentences verbatim (Andre & Sola, 1976). Questions that involve application to new examples, paraphrase, or inferences that go beyond the text can be argued to require deeper processing. But, unfortunately, these sorts of questions are more difficult than verbatim questions. There is a lower probability that students will answer them correctly.

The issue the present research addressed is whether engaging in a task that increases the likelihood of meaningful processing will be facilitative when the task also gives rise to frequent errors. Pairs of sentences containing the same subject noun and last word were constructed. When given a Determined sentence stem, subjects consistently supplied the same last word to complete the sentence. For example, all subjects responded desk to complete this stem: The executive sat behind his large oak _____. When presented the companion Undetermined stem, The executive went to shop for a new _____, many different words were supplied including tie, car, suit, briefcase, and pen. No one produced desk.

Subjects first supplied a word to complete a sentence and then were shown the sentence with the word the experimenter had chosen to complete the sentence. They were told to read the sentence aloud, trying to guess the correct word, and then to learn the experimenter's version of the

sentence. Control subjects simply read the sentences. The sentence completion task was expected to improve the learning of Determined sentences, as it had in the previous studies, since meaningful processing is assured. However, when the sentences were Undetermined, the sentence completion task was expected to disrupt learning. Subjects will almost never complete these sentences with the word intended by the experimenter. The wrong answers should interfere with learning the correct versions.

## Experiment 1

### Method

Subjects. Ninety-six undergraduate students enrolled in an introductory educational psychology course participated in this study to fulfill part of the course requirements. The subjects were randomly assigned to experimental conditions at the time of testing, with the restriction that all cells of the design included the same number of subjects before another subject was added to any cell.

Design. The two main factors in the experiment were experimental task and list type. Experimental task was defined by two levels: In the Reading-Only condition subjects saw the completed sentence and read it aloud, and in the Sentence Completion condition they saw the sentence with a blank in place of the last word and supplied a word to complete the sentence. List type had three levels--Determined, Undetermined, and Mixed. The Determined lists were made of sentences that were constructed so all subjects would report the same last word to complete the sentence, while sentences on the Undetermined list prompted a variety of final words. The Mixed lists included both types of sentences.

Each subject studied two lists. The order of lists was counterbalanced within each treatment condition. Study of each list was followed by two tests. The Forward test presented the subject noun and required the subject to reply with the last word of the sentence, and the Backward test presented the last word of the sentence and asked the subject to report the sentence's subject noun. The order of the two tests was the same across both lists and was counterbalanced between subjects. The Backward test was included as a check on the results of the Forward test. If the Sentence Completion group scored higher on a Forward test than the Reading Only group, it might be proposed that the Sentence Completion group benefited from an uninteresting form of positive transfer from the study task to the test, since the two activities are similar in the Sentence Completion condition. If this advantage were also evident on a Backward test, the most credible interpretation sould be that the Sentence Completion group learned more sentences.

Materials. The Determined sentences were chosen from sentences used in the earlier study (Anderson, Goldberg, & Hidde, 1971). In that study, undergraduates presented with sentences that had a blank in place of the last word were instructed to complete the sentence with the word that "most obviously fit the meaning of the sentence." A sentence was considered Determined if 97% - 100% of the norming sample used the same word to complete the sentence.

For the study reported here, a set of Undertermined sentences was created. These sentences used the same subject noun-last word pairs as

the Determined sentences, but each pair was embedded in a different sentence context so the last word could not be predicted from the first part of the sentence. In order to verify that the last word was indeterminate, the sentences were given to fifty-one students enrolled in an introductory educational psychology class. Each sentence had a blank in place of the last word, and the students were instructed to fill in a word that sensibly completed the sentence. From among the 63 sentences normed, sentences were selected according to the criteria that no more than 50% of the norming sample filled any blank with the same word, and that no more than 50% used the word the experimenter had chosen as correct. The average proportion with which the correct word was supplied was .09 for the set of 48 Undetermined sentences used in the experiment.

Below are two more examples of sentence pairs. The Determined sentence is listed first.

The dove is a symbol of peace.
The dove appeared when the magician said peace.

The physician noted the time on his wrist watch.
The physician asked the patient if he had a watch.

The Undetermined sentences were arranged in two lists of 24 with care to minimize intralist similarity. Then the Determined sentences were arranged into two parallel lists. In addition, Mixed lists, each consisting of 12 Determined and 12 Undetermined sentences, were created. The order of items in these lists conformed to the order in the other two lists. Whether a sentence in the Mixed list was Determined or Undetermined

was a random event, with the restriction that 12 items of each type appeared in each list and that no more than three items of one type occurred sequentially. Two forms of the Mixed Lists were used. The second form was the complement of the first; that is, the sentences that were Determined in the first form were Undetermined in the second, and vice versa.

Procedure. Subjects in the Sentence Completion condition saw a sentence typed on an index card with the subject noun underlined and a blank in place of the last word. This sentence was presented for four seconds while the subject read the sentence aloud and tried to guess the word the experimenter had chosen to complete the sentence. Then the completed sentence was presented for two seconds and subjects read the correct last word aloud. The presentation of the sentences was paced by beeps from a tape recorder. Each subject completed two practice items before studying the first list.

After all the sentences in the first list had been presented once, the subject completed the two tests. For the Forward test, he was given a stack of index cards with the subject noun from one sentence typed on each card. The subject read the word aloud and then reported the last word of that sentence. Each subject could spend as much time on any item as he chose, however, he could not return to any item once he had passed it. For the Backward test, the set of index cards presented the last word of the sentence and the subject was to report the subject noun of the sentence. This test was also self-paced.

Subjects in the Reading Only group saw each sentence for six seconds so the study time for the two treatment groups would be equal. During this interval, subjects read the sentence aloud once. After six seconds, signaled by a beep from a tape recorder, the experimenter turned to the next index card.

After the first list had been presented, the subject completed two tests, and then continued with the second list and the tests. The order of the two lists was counterbalanced across subjects and within experimental conditions, and the order of items within each list was constant for all subjects. The order of the two tests was counterbalanced across subjects and within each experimental treatment. The order of items within each test was constant for all subjects: The first 12 test items were a random arrangement of the first half of the list, and the second 12 items were a random arrangement of the second half of the list. This procedure minimizes effects of short-term memory on recall performance (Nelson, 1970).

## Results and Discussion

The data from Experiment 1 were analyzed using a 2 X 3 X 2 X 2 analysis of variance. Experimental task (Sentence Completion versus Reading Only) and list type (Determined, Undetermined, and Mixed) were between-subjects factors, while list position (first list versus second list) and test (Forward versus Backward) were within-subjects factors.

The analysis identified a significant main effect for list position, $F$ (1,72) = 15.35, $p < .01$, and a significant Experimental Task X List

Position interaction, $F$ (1,72) = 12.87, $p < .01$. This interaction is pictured in Figure 1. Subjects in the Sentence Completion group recalled more sentences than subjects in the Reading-Only group on the first list, but this difference did not appear on the second list.

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Insert Figure 1 about here
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The significant effect of the list position factor indicates that practice on the first list influences performance on the second list. After completing the study and test trials for the first list, the subject has some information about the effectiveness of his processing activities and may modify these procedures before studying the second list.

Because of the interaction of task and list position, performance on the first list is examined in detail. Recall proportions are presented in Table 1. There was a significant main effect for experimental task, $F$ (1,72) = 19.95, $p < .01$, but the main effect for list type and the Experimental Task X List Type interaction were not significant. This means that the Sentence Completion task facilitates sentence learning, and this facilitation occurs regardless of the match between the word supplied by the subject and the word designated by the experimenter.

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Insert Table 1 about here
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Performance on the Forward test was consistently higher than performance on the Backward test, $F$ (1,72) = 38.84, $p < .01$. However, there was not a trace of an interaction between test and task. The lack of an interaction argues against the interpretation that the Sentence Completion

group scored higher than the Reading Only group on the Forward test because there is a closer match between the study conditions and the test conditions for this group. Since performance on the Backward test for the Sentence-Completion group also surpasses the Reading Only group's performance, it seems test performance does measure differences in amount learned rather than transfer between the two tasks.

Experiment 1 confirms the previous finding that the sentence completion task facilitates learning, presumably because the task makes meaningful processing more likely. The unanticipated--indeed, we would say shocking--finding was that the benefits of the sentence completion task extend even to the Undetermined sentences. How could this be when subjects are almost never able to complete any of these sentences with the correct word?

## Experiment 2

The unexpected results of Experiment 1 prompted a re-examination of the sentence completion task. This task can be analyzed using concepts from research with paired-associates. Subjects who received Undetermined sentences are presented with a sentence stem, A, and supply a word to complete the sentence, B. Then they are shown the same stem, A, with the experimenter's word, C, completing the sentence. Thus, the experimental task can be represented as A-B, A-C. In contrast, the experimental task for those who got the Determined sentences can be represented as A-C, A-C, since the sentences are constructed so the words supplied by the subject match those chosen by the experimenter. The unconfirmed prediction that

the Undetermined sentence group would learn fewer sentences than the Determined sentence group was essentially a prediction of negative transfer from A-B to A-C.

We recognize, of course, that the sentence completion task is only a rough analogue of the paired associate task. One difference is that in the former task the "pairs" from the two "lists" are interleaved. Nonetheless, we have previously found the analogy fruitful (Anderson & Myrow, 1971; Kulhavy & Anderson, 1972), so we were not easily dissuaded on the grounds that the correspondence between the two tasks is less than perfect.

How could the failure to find negative transfer be explained within the framework of interference theory? A plausible answer is that it was easy for a subject to differentiate between his word and the correct word. He produces his word and, in contrast to the correct word, it never appears in print. Good response differentiation could explain why there was no negative transfer.

The words the subject produces himself are still a potential source of interference, however, which might manifest itself under some conditions. One such condition is delayed retention. Since both the Determined and the Undetermined sentence groups must learn the experimenter's sentence, the task for the former group is A-C, A-C, recall A-C and the task for the latter group is A-B, A-C, recall A-C. This arrangement corresponds to the classic proactive inhibition paradign. Recall performance in the Undetermined condition should suffer from interference from A-B. Proactive interference effects increase with the length of the interval between learning A-C and recalling A-C. It can be argued that these

effects were not apparent on the immediate recall test used in Experiment 1 because of the very short interval. Experiment 2 tested the hypothesis that the Undertermined group would score lower on a delayed retention test that the Determined group because of interference from the words the subjects supplied during the study trial. The specific reason for interference after a delay should be response competition, caused by loss of differentiability of the subject's words and the correct words.

## Method

Subjects. Forty-four undergraduate students enrolled in an introductory educational psychology course participated in this study to fulfill part of the course requirements. Two other students were eliminated from the sample because they did not return for the retention test, and three others were eliminated because they did not follow the directions. Subjects were randomly assigned to experimental treatments when they arrived for the experiment.

Design. The study used a 2 X 2 analysis of variance design with factors of experimental task and sentence type. As in Experiment 1, there were Sentence Completion and Reading Only groups. The factor of sentence type included two levels: Determined Sentences and Undertermined Sentences.

Materials. From the 48 Undetermined sentences used in Experiment 1, 30 were selected to minimize similarities among subject noun-last word pairs. (For example, one sentence used the word child as the subject, and another used children as the subject, so one of these was eliminated.) For the Undetermined sentences selected, the average proportion of norming

group subjects who supplied the experimenter's word to complete the sentence was .05. The set of Determined sentences consisted of the same subject noun-last word pairs, but used a different context so the last word was consistently predictable from the sentence stem.

For the immediate and the delayed recall tests, the subject noun from each sentence was presented on a separate index card and subjects were instructed to report the last word of the corresponding sentence. Since the Determined and the Undetermined sentences were constructed from the same set of subject noun-last word pairs, the test items were identical for all groups and the response scored as correct for each subject noun was the same for all groups. The order of test items was random, with the restriction on the immediate test that the first half of the test included only items from the first half of the study list.

For the delayed recognition test, the subject noun of a sentence was presented on an index card along with three alternative responses. The alternatives included (a) the correct response, (b) a correct response to another item, (c) the most frequently reported incorrect response for the Undetermined form of the sentence, and (d) the most frequently reported incorrect response for the Undetermined form of another randomly chosen sentence. A unique form of the delayed recognition test was created for each subject who received Undetermined sentences and the sentence completion task. Alternative (c) was replaced with the word the subject had reported during the study interval for the corresponding item. This procedure was necessary since interference effects are not evident on a recognition test unless the

particular competing responses are among the alternatives (Anderson & Watts, 1972). The alternatives were arranged in a random order for each test item. The order of items within the test was identical for all subjects.

Procedure. Each subject completed two practice items before studying the set of 30 sentences. The sentences were presented one at a time in the window of a memory drum. Subjects in the Reading Only groups saw the entire sentence for eight seconds, while subjects in the Sentence Completion group saw the sentence with a blank in place of the last word for four seconds and then the completed sentence for four seconds.

In the Sentence Completion groups, subjects read the entire sentence stem aloud and tried to guess the word the experimenter had chosen to complete the sentence. The experimenter recorded the subject's response. After four seconds, the completed sentence was presented for another four seconds, and the subject read the entire sentence aloud.

In the Reading Only groups, the entire sentence appeared in the window of the memory drum for eight seconds and each subject read it aloud during this interval.

After the sentences had been presented, the subject completed the immediate recall test. When finished, subjects were asked to return at the same time a week later for another experiment. Some subjects asked if the experiment would cover the same material. They were told the procedures would be similar but not identical. The night before the

delayed tests, each subject was called to remind him of his appointment.

Results and Discussion

Immediate Recall. A 2 X 2 analysis of variance of immediate recall scores identified a significant main effect for experimental task, $F$ (1,40)= 13.35, $p < .01$, but no effect for sentence type and no significant interaction. The mean proportions are presented in Table 2. Thus, the results on the immediate recall test replicate the findings of Experiment 1. When subjects supply a word to complete a sentence, learning is facilitated, regardless of the match between the subject's word and the experimenter's word. The absence of an effect for sentence type suggests that both lists were equally learnable.

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Insert Table 2 about here

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Subjects in the Undetermined Sentence Completion group were expected to complete the sentences with words other than those chosen by the experimenter. This did not occur for each item, however. Sometimes subjects did not report any word during the study trial. The mean proportion, $\overline{P}$, of cases in which this happened was .15. Occasionally the subject gave the correct word ($\overline{P}$ = .09). Competition would be possible only on those items where the subjects reported an incorrect word during the study trial. Subjects in the Determined Sentence Completion group were expected to fill the blank with the word chosen by the experimenter, but occassionally they suggested a different word during the study trial ($\overline{P}$ = .02).

For the Undetermined Sentence Completion group, the conditional probability of reporting a correct response, R2, on the immediate test, given that a wrong response, W1, was reported during study was computed, P (R2|W1). This was compared with the conditional probability of reporting a correct answer on the immediate test given that the correct word was reported during the study trial, P (R2|R1), for the Determined Sentence Completion group. If supplying different words results in negative transfer to the task of learning the experimenter's sentence, the Undetermined Sentence Completion group should recall fewer of the items that fit the interference paradigm than subjects in the Determined Sentence Completion Group. In fact P (R2|W1) was .85 and P (R2|R1) was .83, so there was actually a slight trend in the direction of positive transfer.

Delayed Recall. The analysis of variance for this set of scores also shows a significant main effect for the experimental task $F$ (1,40) = 13.18, $p < .01$, but no significant effect for sentence type or the interaction. The task requiring subjects to comprehend the sentence results in higher retention test scores than the Reading Only control group after a one week retention interval.

The most sensitive test for proactive inhibition includes just those cases in which the specific conditions required for interference are present. Within the Undetermined Sentence Completion group, the conditional probability of correct recall on the delayed test, R3, given that a wrong response was supplied during the study trial and the correct response was given on the immediate recall test was computed for each subject. This conditional probability, P (R3|W1R2), reflects just the set of

circumstances that define proactive inhibition. The subject reports A-B during the study trial and had learned A-C as evidenced by his performance on the immediate test. If the subject did not correctly answer the item on the immediate test, or if he matched the experimenter's word during the study trial, the specific conditions for proactive inhibition were not met. For the Determined Sentence Completion group, the conditional probability of correct delayed recall, given that the correct response was reported during the study trial and a correct response was given on the immediate test was computed for each subject. This value, P (R3|R1R2), represents the conditions where no proactive inhibitions is expected, and serves as a standard of comparison for the performance of the Undetermined Sentence Completion group.

If the words the subject supplied during the study trial serve as a source of interference for later recall of the correct response, then P (R3|W1R2) < P (R3|R1R2). This prediction was confirmed. The values computed in the manner just explained were .44 for the Undetermined Sentence Completion group and .58 for the Determined Sentence Completion Group, which is a significant difference, $t$ (20) = 1.77, $p < .05$.

To further document the effect of interference from words reported during the study trial, the errors on the retention test were itemized. Of the overt errors, 29% were words supplied during the study interval. This averaged to 1.45 obviously interfering items per subject.

Delayed Recognition. On the delayed recognition test, subjects were presented with the subject noun of a sentence plus three distractors.

One of the distractors for subjects in the Undetermined Sentence Completion group was the specific word they had supplied to complete the sentence during the study trial. For the Determined Sentence group, this distractor was the word most frequently supplied to the parallel Undetermined sentence. The analysis of variance for these scores shows no significant main effects, but the interaction of experimental task and sentence type was significant, $F$ (1,40) = 6.32, $p < .05$. A further comparison showed, as predicted, significantly poorer performance in the Undetermined Sentence Completion group than in the Determined Sentence Completion group, $t$ (20) = 2.80, $p < .05$.

Conditional probabilities of recognition were compared for the particular interfering items in the Undetermined Sentence Completion Group and the particular non-interfering items in the Determined Sentence Completion Group. This analysis was identical to the one done with delayed recall. The Determined Sentence Group recognized a larger proportion of the items ($\overline{P}$ = .92) than the Undetermined Sentence Group ($\overline{P}$ = .85), and this difference was statistically significant with $t$ (20) = 1.78, $p < .05$. An analysis of errors indicated that 93% made by Undetermined Sentence group were choices of the words reported during the study trial, a fact very consistent with the response competition interpretation.

## General Discussion

Both experiments demonstrated that when subjects provide the last word to complete each of a series of sentences, they learn more

than subjects who simply read whole sentences. This facilitation occurs regardless of the match between the terms supplied by the subject and the ones designated as correct by the experimenter. In other words, neither experiment gave evidence of negative transfer in the condition in which the correct last word could not be predicted and subjects were almost always wrong. However, Experiment 2 showed that errors during acquisitions have disruptive consequences for retention after one week. Proactive interference from the non-matching words supplied during the study trial affected both delayed recall and delayed recognition in the Undetermined Sentence Completion group.

The results of the two experiments parallel findings from research with paired associates. The task of the Undetermined Sentence group can be represented as A-B, A-C, recall A-C, while the task of the Determined Sentence Completion group can be represented as A-C, A-C, recall A-C. The contrast between these two groups resembles the paradigm for demonstrating proactive inhibition in a list experiment, in which responses learned on the first list compete with recall of responses learned on the second list. This model from paired-associate research accurately predicted relative performance on the delayed retention tests.

On the delayed recall test one week after learning, even the Undetermined Sentence Completion group recalled more than its Reading Only control. It is tempting to conclude that the advantage to be gained from tasks requiring the subject to construct meaningful

representations for verbal material outweighs any performance decrements due to interference arising from errors during learning, but we shrink from pushing this implication until studies are completed using a wide variety of materials and a number of different retention intervals.

The task used in these studies resembles the instructional situation in which a student is presented with a question and answers it incorrectly. Results here suggest that if the student is then provided with feedback he will be able to learn the answer, but both the student's wrong answer and the correct answer will compete on a retention test. One way to avoid or minimize this interference would be to prevent errors by carefully structuring the questions within a precise instructional sequence. Another way to minimize interference effects would be to provide further practice with the question and the correct response any time the student answers a question incorrectly. The Distar Reading Program includes such an error correction procedure. When a child or group of children respond incorrectly to a question, the teacher is instructed to give the correct response and then to repeat the question and have the students supply the answer. Siegel (1976) showed that teachers who consistently used this sequence had classes who scored higher on unit achievement tests than teachers who did not consistently use this correction paradigm. In addition, when the less effective teachers were trained in the use of the correction sequence, their classes subsequently scored higher on an achievement test than classes of matched, untrained teachers.

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Table 1

Mean Proportions Recalled on the First Test

as a Function of List Type and Experimental Task

| | List Type | | |
|---|---|---|---|
| Experimental Task | Determined | Undetermined | Mixed |
| Sentence Completion | .77 | .78 | .76 |
| Reading Only | .69 | .66 | .70 |

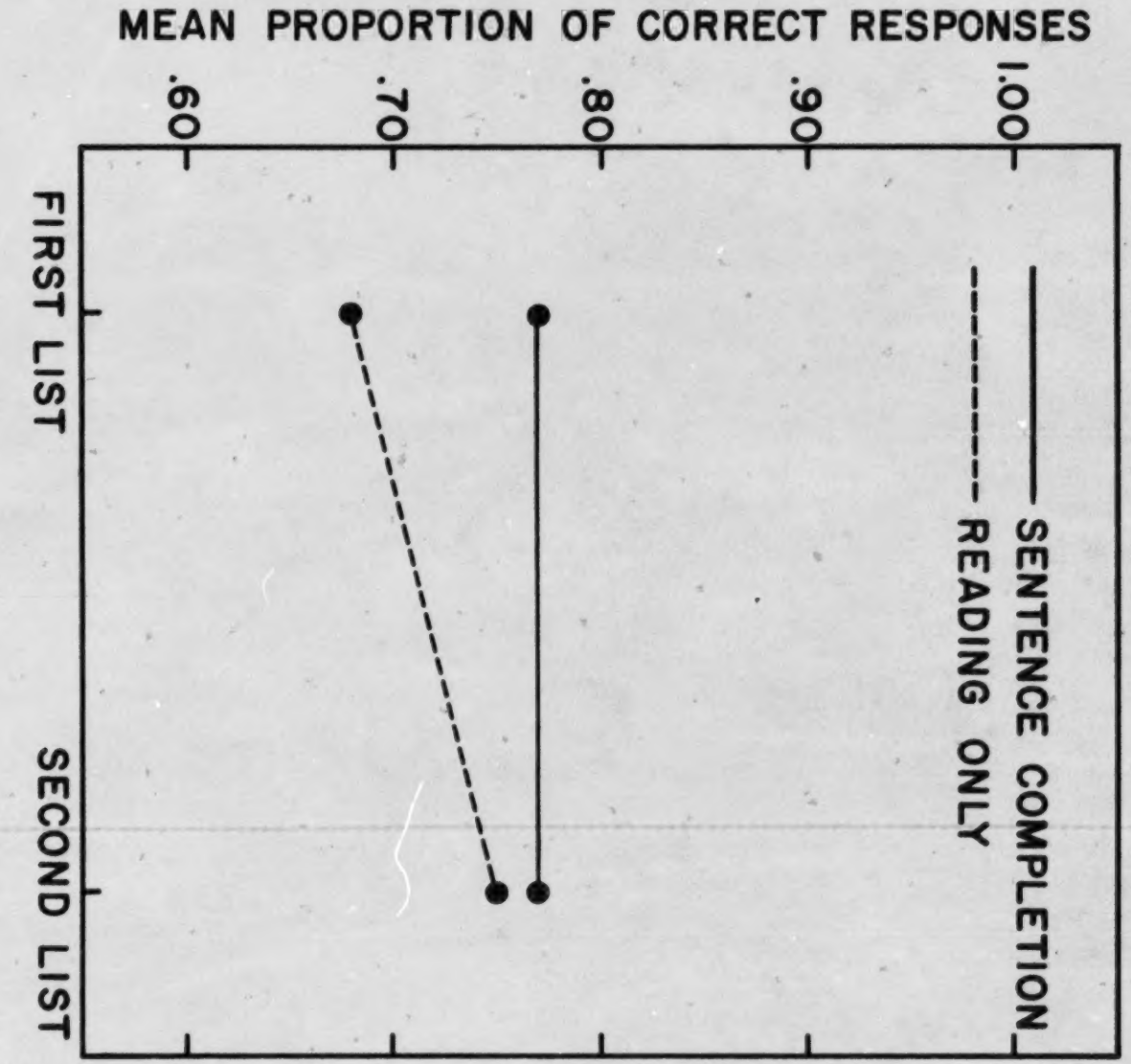
Table 2

Mean Proportion Correct on Each Test in Experiment 2

| Experimental Task | Sentence Type | Immediate Recall | Delayed Recall | Delayed Recognition |
|---|---|---|---|---|
| Sentence Completion | Determined | .84 | .50 | .88 |
| | Undetermined | .83 | .40 | .77 |
| Reading Only | Determined | .69 | .26 | .79 |
| | Undetermined | .65 | .28 | .76 |

## Figure Caption

Figure 1. Mean proportion correct as a function of task and list.


MEAN PROPORTION OF CORRECT RESPONSES
.60
.70
.80
.90
1.00
FIRST LIST
SECOND LIST
SENTENCE COMPLETION
READING ONLY